A Collaborative Virtual Environment for the Simulation of Temporal Bone Surgery

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Purpose
Several common otologic surgical procedures – including mastoidectomy, acoustic neuroma resection, and cochlear implantation – involve drilling through or within the temporal bone. The complex regional anatomy and the use of a high-force tool in a sensitive area suggest computer simulation as a mechanism for training residents. We thus present a framework for visuohaptic simulation of temporal bone surgery.

Materials and Methods
Bone drilling is simulated using a SensAble Phantom haptic device, based on a volumetric point-sampling algorithm that allows direct interaction with volumetric data. A second Phantom simulates the irrigation/ suction tool that is typically used intraoperatively. We also present a hybrid data representation that allows smooth surfaces to be maintained for graphic rendering while volumetric data is used for haptic feedback. This representation easily accommodates both hand-crafted surface models and volumetric image data as input. Drill sound and vibration – critical sources of information about bone structure – are simulated based on experimental data. We incorporated a series of simulated neurophysiology monitoring tools that allow the trainee to avoid critical structures, using feedback similar to that which is available intraoperatively.
Our environment also provides a network interface that allows two users to observe and manipulate a common model, and allows one user to experience the forces generated by the other's contact with the bone surface. This permits an experienced surgeon to "physically demonstrate" correct technique, a novel training mechanism that we hope to explore with further experimentation. The simulation framework is also easily extended to present other procedures that involve similar interactions with the anatomy. In particular, we have adapted our framework to dental and craniofacial procedures and data sets, as we demonstrate at the supplied URL.

Results and Conclusion
We have worked extensively with a collaborating otologist to tune the feedback provided by our simulation, and initial results indicate that it is appropriately realistic and captures the key sources of feedback that guide surgical navigation and decision-making. In the future, we hope to formally explore the potential benefits of our environment for resident training or patient-specific procedure rehearsal, and to explore the novel benefits of our networked-demonstration module.